Embolization of Arteriovenous Malformations Prior to Radiosurgery

S. MIYACHI, M. NEGORO, R. OKAMOTO, G. OTSUKA, O. SUZUKI, J. YOSHIDA

Department of Neurosurgery and Endovascular Neurosurgery; Nagoya University Graduate School of Medicine, Nagoya

Key words: cerebral arteriovenous malformation, embolization, radiosurgery, strategy

Summary

Embolization prior to radiosurgery is useful to reduce the AVM nidus for adequate planning for radiosurgery. In 37 cases we encountered, patients with the least radiosurgical effects had diffuse type nidus, where the feeders embolized with absorbable embolic materials had the possibility of recanalization. The main purpose of embolization is to prevent bleeding while the radiosurgical effects are being fully obtained. Thus, nidus embolization and the occlusion of fistulous feeders, meningeal feeders and intranidal aneurysms using permanent embolic materials are essential, since effective and successful embolization can increase the occlusion rate and shorten the period until complete occlusion following radiosurgery.

Introduction

Recently the role of embolization has become limited by the evolution and benefits for the treatment of arteriovenous malformations (AVMs) by radiosurgery[1-3]. However, the use of embolization does markedly contribute to the success of treatment, especially in cases of high grade AVMs[4-7]. In this report, we describe the strategies and difficulties of endovascular treatment and management prior to radiosurgery based on our clinical experiences.

Material and Methods

Seventy patients with cerebral AVM who were treated with embolization over the past 5 years were examined, of which 47 patients (20 female and 27 male) ranging age from 14 to 70 years (mean age, 38.5 yr) were included in this study. Clinical manifestation was bleeding in 20, symptomatic episodes such as convulsion in 18, and 9 were incidentally found. AVM nidus was located in the rolandic in 13, frontal (non-rolandic) in 6, temporal in 9, medial temporal in 3, parietal in 4, occipital in 3, corpus callosum and cingulate in 3, cerebellum in 2, and brain stem in 2 and nuclear in 2. Size of nidus, which was approximately calculated with half of a multiplier of three diameter of nidus, was very small (< = 5 ml) in 2, small (6 to 10 ml) in 8, moderate (11 to 25 ml) in 22, large (26 to 50 ml) in 14, giant (> 51 ml) in 1. Six cases of AVM belonged to grade I in Spetzler-Martin classification*, 16 in II, 15 in III, 9 in IV, and 1 in V. N-butyl cyanoacrylate (NBCA) (Histoacryl Blue; B-Braun, Melsungen, Germany) mixed with nonionic contrast agent was used in all cases as an embolic material. Sixteen cases of AVM were treated with staged embolization. Four patients with AVM who were treated with embolization and radiosurgery underwent repeated treatments for the remaining nidus. Meningeal feeders were found in 13 cases, 9 of

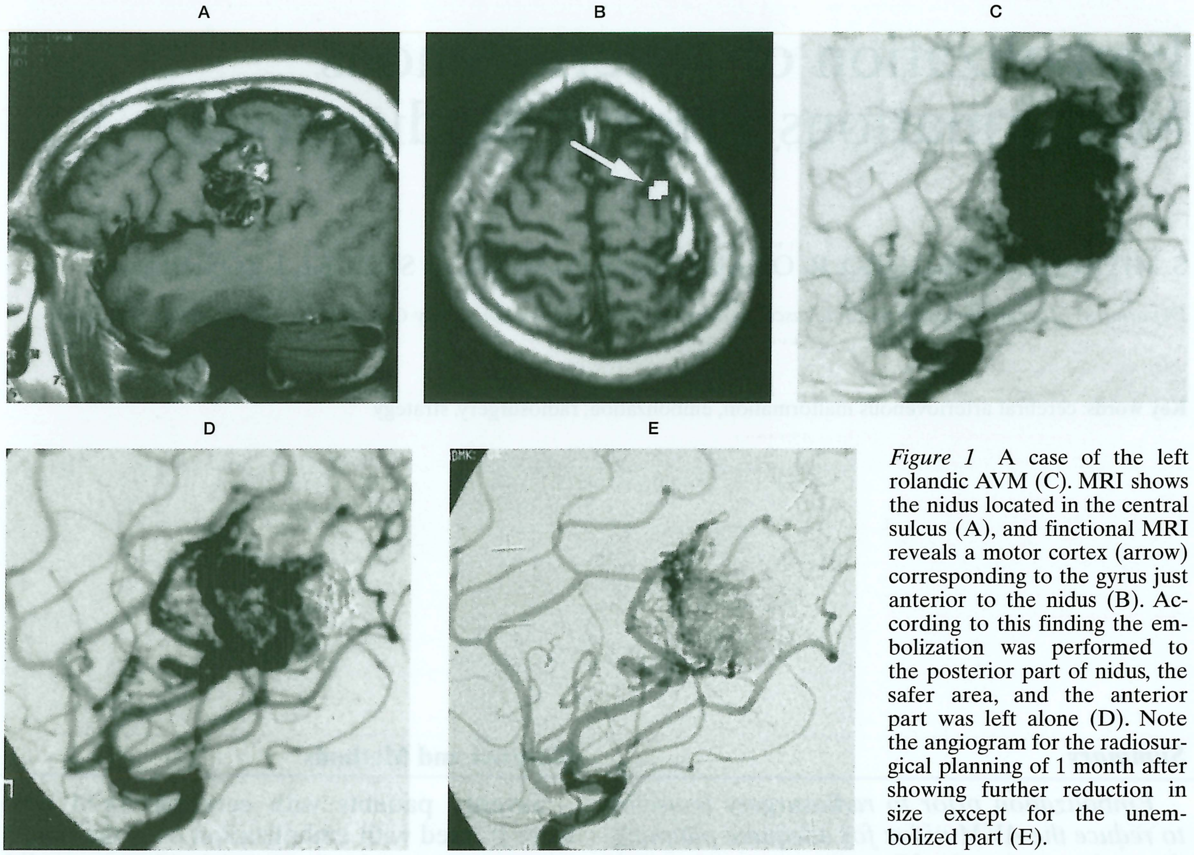


Figure 1 A case of the left rolandic AVM (C). MRI shows the nidus located in the central sulcus (A), and finctional MRI reveals a motor cortex (arrow) corresponding to the gyrus just anterior to the nidus (B). According to this finding the embolization was performed to the posterior part of nidus, the safer area, and the anterior part was left alone (D). Note the angiogram for the radiosurgical planning of 1 month after showing further reduction in size except for the unembolized part (E).

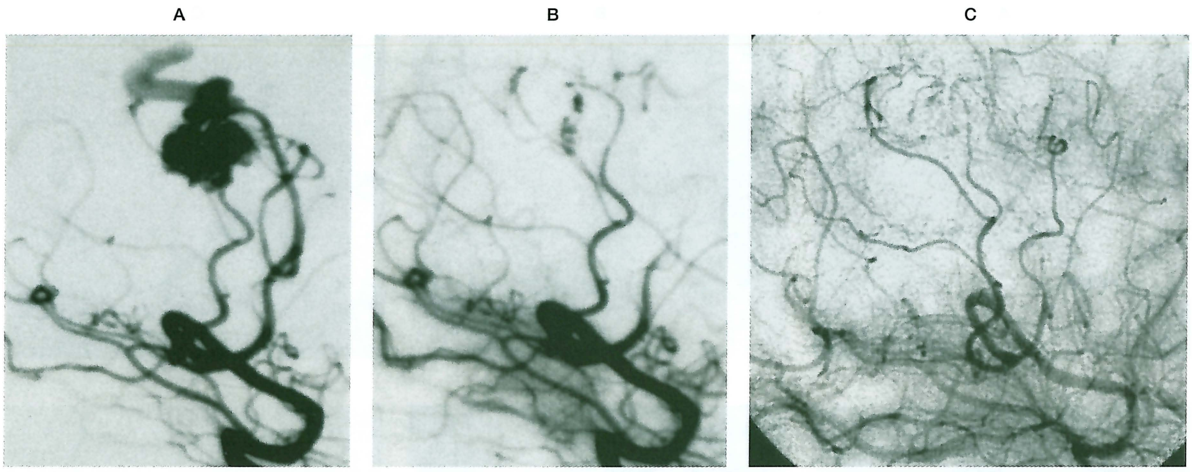
which were embolized. All the patients underwent γ-knife (44 cases) or radiosurgery (4 cases) between 1.5 to 3 months after the embolization except for one case treated less than one months later. The change of nidus size, shunt-flow and feeding pattern were evaluated with comparison between pre-, post-embolization and preradiosurgical angiograms.

Results

Occlusion rate of the nidus was more than 90% in 22, 70 to 89% in 21, and less than 70% in 4. In 20 cases of AVM further size and shunt flow reduction was obtained before radiosurgery (figure 1), in 12 of which nidus were sufficiently packed and 2 of them were found to be completely thrombosed before radiosurgery (figure 2).

The size did not change in 14 cases of AVM and increased in 13 cases including 7 diffuse type AVMs, in most of which the nidus was partially occluded but some feeders resulted in proximal occlusion. In particular, 7 AVMs treated with proximal feeder occlusion alone had regrown before radiosurgery. Although there was no correlation of the location of nidus, the occlusion rate tended to be lower in high grade AVMs like as deep-seated or eloquent ones. Fifteen AVMs disappeared following radiosurgery, all of which were size-reduction or no change cases except for one. Rebleeding following radiosurgery was observed in 2 cases with incomplete (less than 70%) embolization. As permanent deficits, deterioration of hemiparesis in 1, homonymus quadrantanopsia in 1, hearing disturbance in 1, and as temporary deficits, monoparesis in 2, hemidysesthesia in 2, quadrantanopsia in 2, ataxia in 2, and double vision in 1 case were encountered.

Four patients who underwent second combination therapy with embolization and radiosurgery included 1 with temporary AVM treated with only feeder occlusion using detachable coils, 1 with frontal AVM treated with liquid embolic material which had a risk of recanalization, and 2 with temporal AVM with recurrent meningeal feeders which had been embolized with particles (polyvinyl alcohol). In



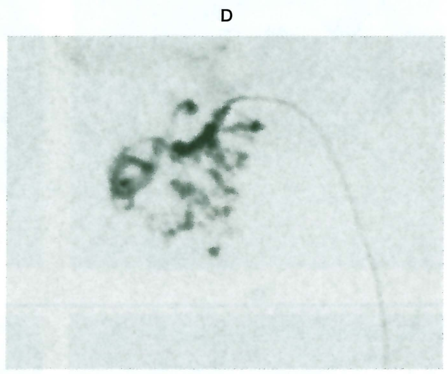


Figure 2 A case with the progressive nidus thrombosis following the embolization. The patient had a small rolandic AVM with a hemorrhage (A). Successful nidus embolization (B) resulted in 90% of size reduction (C). Preradiosurgical angiogram shows the complete occlusion of AVM due to the spontaneous thrombosis of the remnant nidus (D).

the last 2 cases, the recanalized part had been embolized and it had been out of the radiosurgical planning. Thus, the risk of recanalization, which may be disadvantageous for radiosurgery, tends to increase when there is insufficient nidus occlusion, and the reduction of shunt flow and complete breaking of meningeal supply fail.

Discussion

The importance of preradiosurgical embolization is to reconfigure AVMs to promote thrombosis after the radiosurgery [7,9,10]. To assure successful subsequent radiosurgery, the following points should be considered when performing embolization.

Preoperative evaluation

It is very important to evaluate the anatomic angioarchitecture of AVM preoperatively [11,12]. The courses of feeders and drainers as well as the position and distribution of nidus should be identified, and the absence of associated vascular abnormalities such as aneurysms, varix, vasculopathy, stenosis and occlusion should be established. In particular, it is important to get inforamtion on hemodynamics including steal phenomenon, venous congestion, occupation of sinus, and reflux to cortical veins in advance using high-speed diagnostic angiography. In the case of multi-axial feeders and drainers, the area of feeders and drains in the compartmentalized nidus, the existence of daughter nidus, the correlation among the drainers in charge of each compartment, and the influence of the normal draining system should also be checked, using superselective angiography with high frequent exposures. To predict risky feeders in eloquent areas, functional imaging on MR or PET scan may also be useful (figure 1) [10].

Target of embolization

The target of embolization is a nidus of AVM [9,10,13]. Proper embolization of the nidus can promote thrombogenesis due to the stasis from other feeders [14]. In the case of multi-compart-

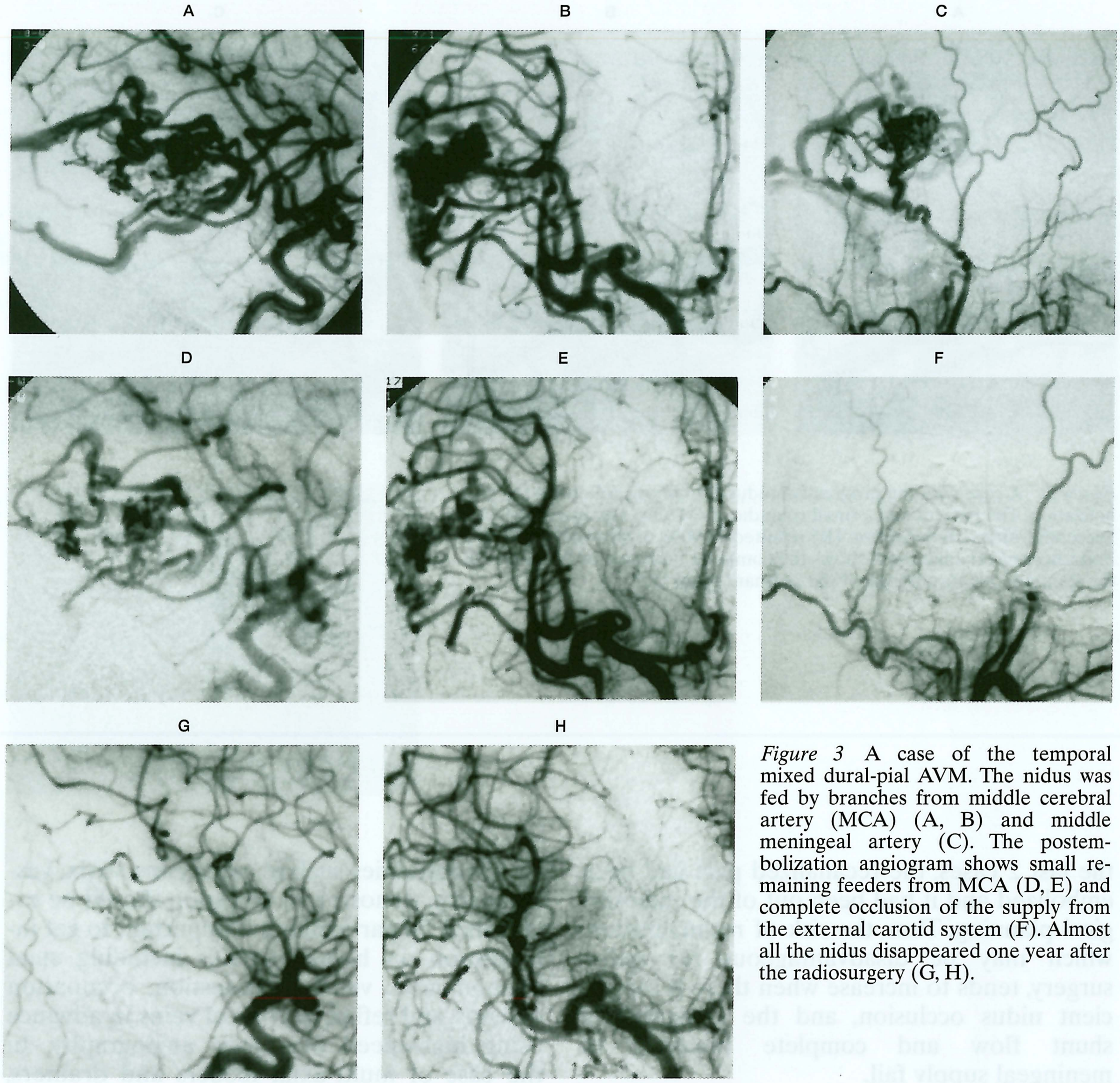


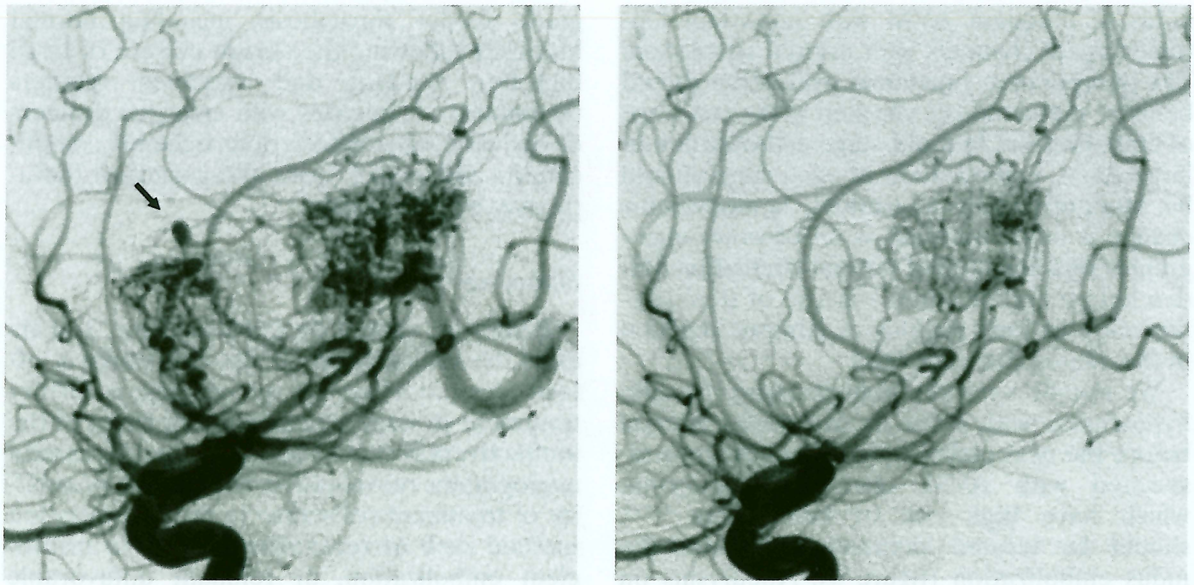
Figure 3 A case of the temporal mixed dural-pial AVM. The nidus was fed by branches from middle cerebral artery (MCA) (A, B) and middle meningeal artery (C). The postembolization angiogram shows small remaining feeders from MCA (D, E) and complete occlusion of the supply from the external carotid system (F). Almost all the nidus disappeared one year after the radiosurgery (G, H).

ment nidus size reduction, each compartment is helpful in establishing the target during radiosurgery. On contrary, the feeder occlusion at the proximal site may reform the nidus into foggy or scattered condition, and may promote the sprouting of new feeders from an adjacent area resulting in a restoration in size [9,10,15,16]. In 47 patients in our series, 12 of 14 patients with AVM with successful nidus embolization obtained further size reduction in preradiosurgical angiogram, 2 of which obtained complete thrombosis before radiosurgery (figure 2). However, 7 of 9 AVMs treated with proximal occlusion alone regrew due to the development of other feeders.

Embolic materials

There should be no possibility of early recanalization caused by the materials used for preradiosurgical embolization, because the effects of radiosurgery cannot be confirmed immediately. In planning radiosurgery the target should be the remaining nidus and the embolized part is out side of the target area, and complete occlusion after radiosurgery is not expected.

Thus, liquid materials are the best for obtaining a permanent occlusion, of which glue (n-butyl cyanoacrylate) is one of the most reliable materials [13,17,18].



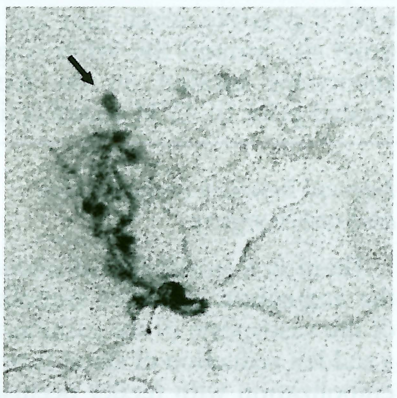


Figure 4 A case with an intranidal aneurysm. The patient has putaminal hemorrhage due to the rupture of the AVM at the basal ganglia (A). A small aneurysm (arrow) was found in the nidus (B), which was suspected to the sourse of bleeding, and was embolized with glue all together with nidus. Remaining AVM (C) was treated with subsequent radiosurgery.

Methods for embolization

The basic method is to pack each compartment of nidus. After the evaluation of the shunt flow on superselective angiography of feeders, it is important that the glue does not pass through into the drainers or occlude the feeders proximally. A diluted glue with a low concentration (20% to 33%) has been proven useful for this in our patients. Before injection of the glue, a provocative test is performed in all cases, except for those undergoing general anesthesia. Glue should be injected slowly with care taken for overembolization, which may occur if too much glue refluxes toward the microcatheter as well as into the other feeders supplying the same compartment of nidus. Intranidal arterio-venous fistula and meningeal feeder should also be treated by embolization because they are resistant to radiosurgical effects (figure 3) [10]. Proximal flow control is useful if there is a possibility of migration of glue into the drainers or the catheterized feeder because of remaining high flow shunts. In multiaxial feeders, minor feeders have priority for embolization, and main feeders should be embolized in multi-stages. However, the remaining tiny feeders with reduced flow can be difficult to navigate with flow-guided microcatheters, particularly those located in the peripheral of nidus of eloquent AVM with important leptomeningeal channels with normal circulation. The preoperative functional evaluation should be more metuculously checked in the last stage of embolization. In multi-stage embolization of large AVM, embolization of each stage should be stopped when a marked hemodynamic change is obtained, such as an obvious angiographic opacification of normal circulation hidden before embolization because of steal phenomenon or long staining of contrast medium in the dilated draining veins.

We usually keep the patient under the mild hypotension with a one or two weeks interval before the next embolization. In aneurysms associated with AVM, intranidal aneurysms, which have high risk of hemorrhage [10,19-24], should be treated simultaneously with the nidus embolization (figure 4). Aneurysms on the proximal site of feeders are embolized with coils, if possible, when they are located at the usual site around the Willis-ring. Flow-related aneurysms, located on the feeders, are not treated prior to AVM embolization [23].

Interval between embolization and radiosurgery

There is a possibility of underestimating on the angiogram just after embolization because of the vasospasm of the catheterized feeders or a sudden reduction of shunt flow. In incomplete embolization with feeder occlusion, redistribution of the nidus flow may enhance the recanalization and regrowth of nidus relatively early. If radiosurgery is performed very soon after the embolization, this false occlusion cannot be predicted and should be excluded from the radiosurgical target. The organization of the thrombosed part of nidus has been reported to be complete within 2 months [25], therefore we suggest that radiosurgery should be performed at least 1 month after embolization [7,26]. During this waiting period, nidus flow may be stabilized, hemodynamic remodeling may progress, and spontaneous intranidal thrombogenesis can be promoted, but care should be taken against overreaction. In particular, retrograde feeder thrombosis, including normal branches following the abrupt closure of large high-flow feeders, and extended drainers thrombosis [27,28], in cases with enlarged drainers or big varix, can cause serious ischemic complications, and in such cases anti-coagulant therapy may be mandatory.

Follow-up

Follow-up should be continued for 3 years after the radiosurgery. If the radiosurgical effects are not observed on imaging, a further treatment strategy is required, and cause of the ineffectiveness should be established by careful angiographic reevaluation. If there is a possibility of treatment resistance to the embolization method such as recanalization due to insufficient embolization, or remnant unfavorable factors against radiosurgery, as mentioned above, further embolization should be planned. Repeated radiosurgery may be performed, and surgical extirpation may be also considered if there are no more feeders available for safe embolization.

Conclusions

Although there have been some negative reports on preradiosurgical embolization [29,30], we suggest that, based on the patients we encountered, embolization contributes to the success of subsequent radiosurgery by reducing and reshaping the AVM nidus for the adequate planning of radiosurgery. Embolization prior to radiosurgery requires permanent and unchanging obstruction of the nidus because the lesion is never extirpated and the effects of radiosurgery are obtained over a period of time. And the main purpose of embolization is to prevent bleeding before the radiosurgical effects are fully obtained.Thus, nidus embolization and the occlusion of fistulous feeders, meningeal feeders and intranidal aneurysms using permanent embolic materials are essential. Effective and successful embolization can increase the occlusion rate and shorten the period until complete occlusion following radiosurgery.

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Shigeru Miyachi, M.D.
Department of Neurosurgery
Division of Endovascular Neurosurgery
Nagoya University School of Medicine
65 Tsurumai-cho, Showa-ku, Nagoya, 466-8550 Japan
E-mail: smiyachi@med.nagoya-u.ac.jp